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**Measuring the quality of publications:
new methodology and case study**

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Abstract

In practice, it is important to evaluate the quality of research, in order to make decisions on tenure, funding, and so on. This article develops a methodology using citations to measure the quality of journals, proceedings, and book publishers. (Citations are also used by the Science and Social Science Citation Indexes, published by the Institute for Scientific Information (ISI), but these Indexes do not cover proceedings, books, and certain journals.) The novel methodology uses statistical sampling, bootstrapping, and classification. This methodology is applied to the field of Information Systems. In this case-study, class-1 turns out to consist of three journals - MIS Quarterly, Management Science, and Communications of the ACM - and two proceedings - VLDB and SIGMOD. The class-1 publishers are Springer, Wiley, and Addison-Wesley. Moreover, hundreds of other journals etc. are classified into a small number of classes.

Keywords: citation analysis, clustering, ranking, statistics, resampling

1. Introduction

In this paper we try to measure the quality of publications in the field of Information Systems, also known as management information systems (MIS) or business computing (we distinguish between the field 'Information Systems' in capital letters and its object of study 'information systems'. Related fields are management, computer, and organizational sciences. We do not focus on Computer Science in general. In §4.1 we shall define this field by specifying which set of journals and proceedings is to be sampled.

The practical problem that motivated our investigation is the evaluation of research by faculty members of the School of Economics and Business Administration (in Dutch, FEW) of Tilburg University (KUB), but obviously similar problems must be addressed by all universities! Before we started, our School had already decided that an important measure for this evaluation should be the ‘impact factor’, defined by the Institute for Scientific Information (ISI), as follows (see ISI 1993, pp. 10-11).

The *impact factor* for journal j in year t is the ratio of (i) the total number of *citations* received by all the articles published in this journal j in the preceding two years $t - 1$ or $t - 2$, from all journals (including *j*) that are included in the ISI data bases, and (ii) the total number of articles in that same journal *j* in the same time window [*t* - 1, *t* - 2]. (For a comprehensive discussion of citation indexing and its use we refer to Garfield (1979).) Note that we may speak of a citing/cited, input/output, or export/import publications.

We emphasize that this definition of impact implies that general journals may have a higher impact factor than specialist journals. Similar idiosyncrasies hold for proceedings and books. Likewise, survey articles tend to receive more citations than technical articles do. Impact factors vary drastically over subcategories: for example, in 1996 the maximum impact factor was 1.777 in the Information Systems subcategory, but it was 2.654 in the Artificial Intelligence subcategory. We suggest to standardize across fields through their median impact factors: divide the impact factor of an individual journal or proceedings by the median value of that whole field (e.g., Information Systems); also see Van Damme (1998, pp. iii, 10, 12). Medians are known to be more robust estimators of location than means or maxima. The use of ranked lists per field implies that scientists working on the 'borderline' of a discipline, may 'shop around' among subdisciplines in the SCI and in the SSCI.

Further, the impact factor varies over time. Our case study is an update of other publications (which, however, use other methodologies). For example, Holsapple et al. (1993, p. 237) concludes that citation patterns do change over time: proceedings have shown an increasing trend, whereas books have shown a decreasing trend. But Hardgrave and Walstrom (1997, p. 121) states: 'The "top 10" journal rankings have shown relative stability since 1991'. Also see Walstrom et al. (1995, p. 106) and Van Damme (1998, p. 16).

Given the decision to use impact factors, a practical problem is that members of our department of Information Systems ('bestuurlijke informatiekunde' or BIK) claim that *proceedings* are an important publication outlet for this new field; ISI, however, measures impact factors for only a few proceedings, none in Information Systems! Moreover, ISI does not rank all journals that are considered to be relevant for Information Systems; examples are many new journals and European journals. (For different fields, Van Damme (1998, p. 9) gives percentages of articles published in ISI journals; for example, in Economics this is 58%, whereas in Information Systems it is only 12%.) Finally, ISI does not collect references to books.

So our main problems are (i) to rank non-ISI journals relative to ISI-journals, and (ii) to rank proceedings relative to ISI-journals. To solve this problem, we use a *sampling* approach.

First we sample one article from each journal - ISI and non-ISI - that we think is relevant for Information Systems (second, we sample articles from proceedings; see next paragraph). This population consists of 170 journals, but some journals are rejected (see below) or cannot be retrieved. Altogether we sample 123 journal articles. Next we collect the list of references per article, and we count how many times a specific journal, proceedings, or book publisher is cited.

There may be ‘inbreeding’: authors refer relatively often to articles in the journal or proceedings that publishes their paper (also see Suomi (1993), who studies American versus European inbreeding). Therefore we take a second sample that comes from a (citing) population of *proceedings* in Information Systems.

Our methodology implies sampling error. This error is measured through 1 - α confidence intervals. To obtain these intervals, we use a statistical technique called *bootstrapping*. This technique gives estimated distribution functions (EDFs, cumulative frequency distributions), which we use to place publications into a number of *homogeneous quality classes*.

We organize this paper as follows. In §2 we detail reasons for measuring quality, and we give references to the literature. In §3 we spell out our assumptions, so the readers can judge the generality of our methodology. In § 4 we discuss details of our methodology. In §5 we apply this methodology to the field of Information Systems, and give the results of this case study. In §6 we summarize our conclusions. Three appendixes give details. (A short version of this paper is Kleijnen and Van Groenendaal 2000.)

2. Quality measurement in the literature

The search for the ‘holy grail’ of measurable quality is not new. For example, Holsapple et al. (1993) lists seven studies on the quality of Information Systems publications; these studies were published between 1982 and 1991. We add some more publications: Anbar (1997), Cheng et al. (1996), Hardgrave and Walstrom (1997), Nord and Nord (1995), Ramesh and Stohr (1989), Robey et al. (1998), Van Heck, Papazoglou, and Ribbers (1997), and Walstrom, Hardgrave, and Wilson (1995). Journals in many other research areas have also been classified; for example, Holsapple et al. (1995) classify journals on Decision Support Systems, and Tahai and Rigsby (1998) review and classify the field of Accounting.

In general, the discussion on the measurement of the quality of scientific publications and research has intensified over these last years, as witnessed by articles in the scientific and the popular press; see Van Dalen (1997), Van Dalen and Henkens (1999), Van Damme (1996, 1998) and also Pieters et al. (1999). (Many more references - mainly to Dutch publications - may be obtained from the authors.) Various reasons for identifying the ‘best’ publication outlets are discussed in Holsapple et al. (1993) and Walstrom et al. (1995); for counter-arguments see Woolsey (1978).

In both the literature and practice, ISI's *impact factor* plays an important role. Its definition (see §1) tends to discount the advantage of larger and older journals. Holsapple et al. (1994), however, normalizes by taking into account the number of years a journal has been published. Van Damme (1998, p. 9) also gives a critique on the impact factor. Note that the impact factor’s numerator (number of citations) and denominator (number of articles) are also published individually, so we might decide to use only numerators to rank publications (see below).

ISI has three data bases, which together cover 6,000 journals from 60 countries! The impact factors are computed from all three data bases; see ISI (1993, p. 7). However, we expect that the third data base does not contain journals that refer to Information Systems publications, so only two data bases are important for Information Systems, namely the *Social Sciences Citation Index* (SSCI) and the *Science Citation Index* (SCI). Holsapple et al (1993) uses the SSCI only. However, the other data base, SCI, does contain the category ‘information systems’, and it ranks well-known Information Systems journals such as *MIS Quarterly* and *Wirtschafsinformatik*. So for our sample we shall use both data bases, and some more sources (see below).

The impact factor’s definition includes a *time window* of two years. Nevertheless, ISI (1993, p. 6) itself states: ‘In some fields, five-year impact factors may be more appropriate ...’. Van Damme (1998, p. 9) says: ‘in economics, the impact usually reaches a maximum ... in the third or fourth year’. So we conclude that a two-year window is too small for Information Systems: top journals in Information Systems have long publication delays (the refereeing process takes long). Therefore we shall concentrate on an infinite time window: we count all references to articles published in a particular journal (e.g., *CACM*) - whatever the publication date of that cited article is; these references are collected from the reference list at the end of the sampled article (e.g., *MIS Quarterly*). (A peculiar example is the 21 references that *Econometrica* received from a single article sampled from *Journal of Group Decision and*

Negotiation, *JGDN*; see §5.)

Our School uses the ISI impact factors; see Van Damme (1996). This approach is expected to be followed by all thirteen Schools of Economics and Business Administration in the Netherlands. This approach, however, misses important information: ISI does not give impact factors for proceedings, books, and certain journals. To evaluate the relative importance of the three types of media, Holsapple et al. (1993, p. 234) gives the relative number of citations: 53.7% for journals, 34.8% for books, and 11.5% for proceedings. (Unfortunately, Holsapple et al. gives neither the titles of these proceedings, nor the publisher names.) For Artificial Intelligence, Cheng et al. (1996) give the following percentages for 1993: 43, 24, 26. Besides the question about the importance of proceedings relative to journals, there is the question about the ranking of proceedings among themselves. Hardgrave and Walstrom (1997, p.123) mentions that the respondents of their questionnaires rank five conferences as top meetings; see Appendix 1 for names (we shall return to this top-five). An older, slightly different ranked list of conferences (based on a 1991 study) is published in Walstrom et al. (1995).

The ISI data bases are available (not free of charge!) to the public. ISI is a well respected institute; for example, its SCI is the basis for a recent article (on the scientific wealth of nations) in the prestigious journal, *Science*; see May (1997). The other data base, SSCI, is the sole data source for some other recent publications: Holsapple et al. (1993, 1994), and Van Witteloostuijn and Boone (1996).

3. Assumptions of the new methodology

Our methodology is based on the following six assumptions or principles.

Assumption 1: *Proceedings* should be evaluated in the same way as journals are.

Assumption 2: The quality of journals should be evaluated in an *objective* way.

Corollary: We do not evaluate the quality of journals in a subjective way; that is, we do not focus on peer review.

Comment: Several publications give examples of publication rankings in Information Systems based on peer review or ‘opinion surveys’; see Hardgrave and Walstrom (1997), Holsapple et al. (1993), Nord and Nord (1995), Van Heck et al. (1997), and Walstrom et al. (1995). One of the authors of the present paper (Kleijnen) participated in such a peer review, which resulted in the list of ranked journals in economics and business administration published by the Society of

Cooperating Netherlands Universities (VSNU). ISI (1993, pp. 6-7) also mentions the importance of peer review, besides citation numbers. We do use peer review to validate our results; see Assumption 4.

Assumption 3: Objective evaluation requires a *formal model*.

Comment: Our School has decided to apply a formal model that relies on ISI impact factors; see Van Damme (1996, 1998). Obviously, there are other important factors when evaluating the 'performance' of a faculty member; for example, student evaluations of teacher performance, financial revenues of applied research and consulting, and development of software. There are other objective measurements besides impact factors or - more generally, citations: rejection rates, number of book copies sold, etc. We, however, focus on citations because of our School's decision. Clearly, any formal model is only a decision support tool.

Assumption 4: Any model needs *validation*.

Validation in discussed in Kleijnen (1999), and on the web (http://manta.cs.vt.edu/biblio/)

Corollary: Peer review is important for any model.

Comment: There are many types of validation, objective or subjective. One important subjective type of validation is 'face validity'; that is, does the model give results that agree with the experts' expectations? In our case, the goal of the model is to evaluate the quality of publication outlets, so we claim that peer review is a good method for validation. An example is the list with five conferences in Hardgrave and Walstrom (1997) (see Appendix 1). We expect that the proceedings of these conferences will turn up among the top proceedings identified through our methodology. Another example is the list of top journals selected through citation analysis in Holsapple et al (1993); many of these journals also turn up in other lists (see Anbar (1997), Hardgrave and Walstrom (1997), Nord and Nord (1995), and Walstrom et al. (1995)). Indeed, Van Damme (1996, p. 14) reports for physics research in the Netherlands: 'It turned out that no major changes in the perceptions of the research were induced within the committee by these [bibliometric] data'.

Assumption 5: Statistical procedures may be used to derive a number of homogeneous quality classes or clusters.

Comment: Cardinal numbers (e.g., impact factors or their numerators) give more information than ordinal numbers - namely, quality class 1 (or A), 2 (or B), etc. Yet, Holsapple et al. (1993, pp. 238-242) distinguishes only two classes or 'tiers' (which are a compromise among the outcomes of several studies). Nord and Nord (1995) also presents two tiers only. The

Dutch VSNU distinguishes five classes. If classes are to be used, then the next question is: how many classes (two, five)? Unlike Holsapple et al. (1993), we are ‘given the latitude to place journals into [an arbitrary number of] tiers’. We might apriori decide to distinguish (say) five classes. However, such a decision seems rather arbitrary. Therefore we apply statistical methods, namely bootstrapping and a simple clustering heuristic based on confidence intervals. (We might test the correlation between the rankings resulting from our procedure and from the ISI impact values; however, we collect citations from Information Systems publications only, whereas ISI collects citations from all fields.)

Assumption 6: Citation patterns in journals and in proceedings are *different*.

Comment: In §1 (Introduction) we have already mentioned inbreeding. In our first subsample we restrict our citing population to journals only (ISI and non-ISI); Holsapple et al. (1993) also uses a sample of journals only, when evaluating journals, proceedings, and books. In our second subsample, however, we use a population that consists of proceedings in Information Systems.

4. Methodology: sampling, bootstrapping, and clustering

We discuss the following three steps of our methodology: sampling (§4.1), bootstrapping (§4.2), and clustering (§4.3).

4.1. Sampling

Because of time and personnel constraints, we restrict our investigation to a sample of citing publications. An important practical question is: how to define the *population* of those citing publications? Because the SCI and SSCI contain both high quality *and low quality* journals, we indeed sample each journal in that population, except for the following.

To save time, we do not sample from those journals that we expect to be cited very rarely in the field under study (say) Information Systems. An example is *Cognitive Brain Research* or *CBR* (#32 in Appendix 2). If we kept *CBR* in our sample of citing articles, we would find out that the publications that *CBR* cites will end at the bottom of our ranked list of Information Systems publications. But we are not interested in such low quality publications on Information Systems, even though these publications may be high quality publications in brain research.

Why do we expect significant differences between the (ISI-journal) rankings in our sample and in the ISI population? A journal may be unimportant for Information Systems, whereas that same journal may be important for a different field. For example, *Econometrica* is cited by only one publication in our case study, so this journal ranks low in our Information Systems ranked list of publications, whereas it is a key journal in econometrics. Further, sampling and measurement errors result in imprecise impact values. Finally, impact factors change from year to year. Fortunately, exact values are not so important when we cluster publications into homogeneous classes.

To avoid bias created by citation patterns we also use a second population consisting of citing articles in *proceedings*.

In our investigation we also include *cited books*. Books may form basic knowledge in a discipline. (Nederhof 1989 also emphasizes the importance of books, albeit in psychology.) Van Heck et al. (1997, p. 9) gives a list of publishers in Information Systems; we may use this list to validate our results. (Van Damme (1996) also gives a list of publishers in the discipline of economics, but his list misses well-known publishers in Information Systems.) Technical details of our sampling procedure are given in Appendix 3.

4.2 Bootstrapping

To estimate the *accuracy* of our sample results, we use bootstrapping. We measure accuracy through $1 - \alpha$ confidence intervals for the number of citations received per journal, proceedings, or book publisher, where α denotes the type I error probability per interval. Such intervals are indeed provided by bootstrapping, without assuming a specific (say, Gaussian) distribution. (Bootstrapping is related to jackknifing and permutation testing: jackknifing is a linear approximation to bootstrapping, which in turn is a sampling approximation to permutation testing.)

The seminal book on bootstrapping is Efron and Tibshirani (1993) (more than 400 pages). A more technical monograph on bootstrapping (500 pages) is Shao and Tu (1995); a short introduction (70 pages) is Mooney and Duval (1993).

Efron and Tibshirani (1993, pp. 115, 383) state that ‘bootstrapping is not a uniquely defined concept ... alternative bootstrap methods may coexist’. We interpret bootstrapping for our situation as follows. The *basic idea* of bootstrapping is: what happens if a specific citing (not cited) article is 'forgotten'; what if this article is counted twice; what if it is counted three times; and so on. In other words, what happens if citing article 1 gets a weight of zero, whereas article 2 gets a weight of two, etc.? The total sample size is kept fixed.

The *technique* works as follows. We define $\boldsymbol{x}_i$ as the reference list of sampled citing article i with fixed sample size n (i = 1, ..., n). So $\boldsymbol{x}$ is a list of cited publications; $\boldsymbol{x}$ is a vector or multivariate non-numeric variable. The basic assumption of bootstrapping is that the n original sample observations $\boldsymbol{x}_i$ (with i = 1, ..., n) are *identically and independently distributed* or i.i.d.: $\boldsymbol{x}_i \sim F$. We assume that this assumption holds. Bootstrapping means that we resample - with replacement - the reference list of each citing article in the sample such that the sample size remains fixed at n . So each list is resampled with equal probability: if the superscript * denotes a bootstrapped value, then $x_i^* \sim \hat{F}$ with $\hat{F}$ = 1/n. Obviously, this resampling results in different values for the number of citations per publication outlet (journal 1, etc.).

We repeat this whole resampling procedure (say) B times; we use a classic value for B, namely 1,000. This gives B observations on the number of citations received by a specific journal, proceedings, or book publisher. These B observations give a so-called bootstrapped EDF. To estimate the lower point of the 1 - α confidence interval, we use the estimated α quantile, namely the order statistic $\hat{F}_{(\alpha B)}$ where we ignore the integer constraint for αB; see the figures below. The original estimate lies within this interval (unless the pseudorandom numbers used to resample, are completely nonrandom; see next paragraph).

Fortunately, we can *implement* bootstrapping efficiently, as follows. The original reference list of citing article i (that is, $\boldsymbol{x}_i$) receives weight $w_i \in$ {0, 1, ..., n} such that these weights sum up to the fixed sample size n: $\sum_{i=1}^{n} w_i = n$. We apply Monte Carlo or simulation to sample these weights from a multinomial distribution, as follows. By definition, Monte Carlo uses pseudo-random numbers (say) r, uniformly distributed on the interval from zero to one: $r \sim$ U(0, 1). So we take a random sample of size n for r from U(0, 1). After initializing $w_i = 0$, we use these n random numbers r_i: if $(i - 1)/n \leq r_i < i/n$ then $w_i = w_i + 1$. (To obtain normalized weights that sum up to one, we could define $p_i = w_i/n$.) Now we use Table 1, as follows.

The number in a cell of Table 1 denotes the number of times the citing article in the corresponding row refers to different articles in the journal or proceedings in the corresponding column; in the case of books the number denotes the number of cited books published by the same book publisher. In the example, the first citing article, A_1, refers to three other (cited) articles in the same journal J_1, to one article in P_2 (the second proceedings in the sample), and to no books. The second citing article, A_2, refers to five cited articles in the first journal and to one article in the citing journal, J_2; it also refers once to P_1 and P_2, and to two books published by B_1. The last article in the table, A_{205}, has a much longer list of references, namely at least 33 references. In general, we denote the numbers in a table such as Table 1 by $y \in \{0, 1, 2, ...\}$.

The *bootstrapped citations* for column 1 become $y^*_{i;\,1} = y_{i;\,1}\, w_i$ (the original sample gives outcomes that result from taking equal weights, $w_i = 1$). In general, the bootstrapped variable in column h becomes $y^*_{i;\,h} = y_{i;\,h}\, w_i$ with $h = 1, 2, ..., H$ and H denoting the number of cited documents (H is unknown at the start of our sampling; however, H is known, once the sample has been collected and processed.)

Obviously, the *cumulated* number of times that the cited publication medium h has been referenced in the n citing articles is $y^*_{.\,h} = \sum_{i=1}^{n} y^*_{i;\,h}$. (Our technique resembles the 're-sampling vector ***P****' in Efron and Tibshirani (1993, pp. 130-133).)

Bootstrapping gives an EDF for the total number of times a particular journal, proceedings, or book publisher is cited in our sample; Figure 1 gives an example (discussed below).

Bootstrapping suggests a natural way to account for the fact that we sample *only one article per journal*, whereas we sample *two articles per proceedings* (which biases the results because of citation patters): when bootstrapping we count the citing journal articles twice. Such bootstrapping implies that the total sample size increases from 205 (= 123×1 + 41×2) to 328 (= 123×2 + 41×2).

4.3 Clustering into quality classes

The bootstrap EDFs give $1 - \alpha$ confidence intervals, which we use to cluster the individual journals and proceedings into classes (we cluster book publishers separately). We propose the following heuristic.

All members of a class should be able to compete with the *class leader*. To find this leader of the top class, we start with a list of all cited journals and proceedings sorted from most often cited to least often cited. We compute the α quantile (lower bound of $1 - \alpha$ confidence interval) of each bootstrap EDF, and find the highest of these quantiles. This maximum estimates the lower limit of the 1 - α confidence interval for the top journal or proceedings; for example, *CACM* in Figure 1. We place the next best journal or proceedings in the same class if the *upper* value of its 1 - α confidence interval exceeds the *lower* value of the 1 - α confidence interval for the class leader; see *MISQ* in Figure 1.

Next we consider the following publication (publication 3) in the sorted list. We compute its 1 - α quantile, and place publication 3 (*Management Science*) in the same class if this value exceeds the lower limit of the confidence interval for the best publication (*CACM*).

We proceed in this way, until a journal or proceedings does not pass this test. In Figure 1 and Table 2 we have five publications in class 1; the leader of class 2 is *Administrative Science Quarterly (ASQ)*. Obviously, we can decrease the number of resulting classes by increasing the value of α (type I error probability per confidence interval; this value α does not imply that the overall confidence in the total ranking is 1 - α). We use α = 0.10.

5. General Results for an Information Systems Application of the Methodology

To define the *population* of citing publications, we combine ISI with Holsapple et al. (1993) and Van Heck et al. (1997), as follows.

ISI distinguishes *subject categories* or (sub)fields. Its SCI covers the category ‘Computer science’, in which we consider the following two subcategories to be relevant for Information Systems: *Information Systems* and *Artificial Intelligence*. So we exclude five other *sub*categories: Cybernetics, Hardware & Architecture, Interdisciplinary Applications, Software Graphics Programming, and Theory & Methods. Further, we exclude categories such as Information Science & Library Science and Telecommunications, because these categories do not seem to contain journals that refer to Information Systems publications. (Cited - not citing - journals may fall into the excluded subcategories and categories.)

ISI does not include all Information Systems journals that are judged to be important by Information Systems experts (see §1). Therefore we also use a list with about eighty Information Systems journals in Holsapple et al. (1993, pp. 236-237) and Van Heck et al. (1997). Some of these journals are also listed in the SSCI. The resulting total population consists of the 170 Information Systems journals listed in Appendix 2.

A practical complication is that names of journals may be obscure: some citing articles use abbreviations; spelling errors occur, names change, and so on; for example, *EDP Analyzer*

(#53 in Appendix 2) changed its name into *IS Analyzer*. To verify names, we use Salk (1995)'s Ulrich directory or the web page 'www.pica.nl'. Nevertheless, our methodology implies measurement errors, besides sampling errors. Some consolation is that ISI is also imperfect: author names are incomplete, etc.

To save time, we do not sample from those journals that we expect to be cited very rarely in Information Systems; an example has already been given, namely *CBR* (#32). More examples are given in Appendix 2; see the journals #22, 25, 53, 108, 161.

Other journals are eliminated because they ceased to exist (# 11, 24, 38, 46, 60, 98, 110, 146, 150, 168). Furthermore, some journals have no references at all (# 27, 53, 59, 68, 107, 134, 157). Finally, some journals we could simply not locate (#36, 96, 123, 140, 141, 152). *Altogether we sample 123 journal articles.*

From the population of citing Information Systems journals we sample *the most recent issue available in 1998*, unless this issue is a Special Issue.

Subpopulation 2 consists of (citing) *proceedings*. For our subpopulation 2 we use two sources: (i) the seventeen proceedings listed by Van Heck et al. (1997), and (ii) the fifty proceedings that are cited most often by the journal articles sampled in subsample 1. Altogether, we have 59 proceedings. We sample two articles (instead of one) from each proceedings, for two reasons: (i) articles in proceedings tend to have fewer references, and (ii) we have fewer proceedings than journals: 59 versus 170 (some proceedings occur in both sources; they are not counted twice).

As with journals, we had some practical problems when trying to obtain specific proceedings; for example, we could not get a copy of *Proceedings of the International Conference on Foundations of Data Organization and Algorithms*. One proceedings turned out to be the same as another one, but with a different - though similar - title. These problems implied that we did not sample 59 proceedings, but only *41 proceedings*.

Our sample gives many data on citing and cited publications. These data we store in a data base using the Access software. This yields the following information. We have *123 citing journal articles and 82 proceedings articles, which refer to 6,901 publications*, namely 3,128 journal articles, 1,532 proceedings articles, 1,577 books, and 664 other publications (such as working papers).

The smallest sampling error results when we take an *unlimited time window*. This gives Table 2, which lists journals and proceedings ranked from top to bottom, based on the number of citations received (numerator of ISI impact factor). Table 3 ranks book publishers. Let us consider these tables in some detail.

Our first impression is that the rankings for journals in Table 2 has face validity. Clearly there are three top journals: *Communications of the ACM* (*CACM*), *MIS Quarterly* (*MISQ*), and *Management Science* (*MS*). The first two journals, *CACM* and *MISQ*, also feature among the top-five US journals selected by Holsapple et al. (1993, p. 234) - see Appendix 1 - and they are also listed among the twelve journals studied by Suomi (1993). The third journal, *MS*, is not in the top-five; we think that this happens because that journal is not restricted to Information Systems.

Note that *CACM* and *MISQ* had ISI impact factors of 2.185 and 1.569 respectively in 1996. These scores, however, are collected over all fields, not only Information Systems. This explains why the ISI topper *Science* (impact of 23.605) turns up in our class 4 only.

Altogether there are six classes; the lowest class consists of journals and proceedings not cited in our sample. To save space we list only the first four classes in Table 2.

Table 2 implies *rankings for proceedings*. Class 1 has two proceedings, namely *Proceedings of the International Conference on Very Large Databases* (*VLDB*) and *Proceedings of the ACM Conference on Management of Data* (*SIGMOD*). These two proceedings are *not* among the top-five conferences in Hardgrave and Walstrom (1997, p.123); see Appendix 1. One explanation may be that those authors use a questionnaire, not citations. Another explanation may be that *VLDB* and *SIGMOD* report on generalist meetings, not on meetings focused on information systems.

Hardgrave and Walstrom's top-five proceedings further includes *ICIS*, which we find in our class 3 (that class has 49 members). Their top proceedings *HICSS* features in our class 4 (132 members). (Suomi (1993) also mentions *ICIS* and *HICSS*.) Their top *IFIP* turns up in our class 4 (282 members). Their top proceedings *IFIP* turns up in our class 5 (225 members). We cannot find their top proceedings *DSS* and *DSI* in our table, either because these two proceedings are never cited in our sample or because the names are misspelled; also see class 6 with its 621 members plus all members not explicitly mentioned because they were never referenced by any of the citing articles in our sample. (Furthermore, Van Heck et al. give a list of seventeen important proceedings; all except one occur in our list: two in class 1, none in class 2, four in class 3, two in class 4, five in class 5, and three in class 6.) Altogether we classify 1,063 journals and proceedings.

We conclude that unfortunately our ranking of proceedings seems to have *less face validity*! Causes may be: sampling error (a sample size of 205 citing articles is too small), bias (our citing population is not representative for Information Systems), or generalist versus specialist proceedings. We find it interesting that *proceedings occur in all quality classes*, including class 1. However, in the top classes most publications are journals, not proceedings. Our interpretation is: articles in proceedings do have impact, but they should be considered preliminary publications that should be followed by publication in journals. (Of course, this ranking is based on an infinite time window, no correction for size, particular definition of citing Information Systems journals and proceedings.)

Table 3 ranks *book publishers*. The three top publishers are Springer, Wiley, and Addison-Wesley. These publishers are indeed well-known in the Information Systems field. Springer's position may be explained by the many Lecture Notes and books reporting on conferences that are not organized yearly. Note that we list Elsevier and North-Holland as two separate publishers (see classes 3 and 4), whereas these publishers are parts of a single company (Reed-Elsevier). In general, it is not always clear how to define a particular book publisher (Wiley US versus Wiley UK?), whereas it is very clear how to define a specific journal (*Management Science*). Therefore Table 3 should be interpreted with care. (Van Heck et al. give a list of twelve important book publishers; they all occur in our list: three in class 1, two in class 2, six in class 3, and one in class 4.) Altogether there are eight classes; only the first six are listed in Table 3.

Querying our data base gives Table 4, which lists the relative number of references *by* articles in journals and proceedings respectively *to* the four types of publications distinguished. This table shows that journals refer more to journals than proceedings do: 48.7% versus 33.5%. Yet, proceedings refer (slightly) more often to journals than to proceedings: 33.5% versus 32.0%. (Further querying of the data base shows whether a particular proceedings refers mainly to journals or not; for example, *HICSS* articles cite many journals.)

We can test statistically whether the two distributions of references by journals and proceedings to journals, proceedings, books, and others are equal. For this test we use a χ^2 test on differences in probabilities; see Conover (1980, pp. 153-8). In our case the χ^2 random variable has (2 - 1)(4 - 1) = 3 degrees of freedom. From Table 4 we compute the value of the test statistic: 180.3. This value is highly significant, even at a type I error probability of 0.1% : $\chi^2_{3;\ 0.001} = 16.26$. So we conclude that there is a significant difference between citation patterns of journals and proceedings.

Upon further querying our data base, we find that the median number of references is 25 in our sampled journals; it is 16 for proceedings. The actual numbers vary between 1 and 125 for journals, and between 1 and 49 for proceedings. The overall median is 19.

A final query is: what happens if we reduce the *time window* to two years - as ISI does? Obviously, a smaller window reduces our sample size - so more noise is introduced - and misses the true impact of publications - which reaches its peak after more than two years. (We did some more sensitivity analysis on the time window; results may be obtained from the authors.)

Figure 1 illustrates how we use bootstrapping to determine *classes*. This figure displays six EDFs for the total number of citations received by the top publications, namely the top-three journals, *CACM*, *MISQ*, and *MS*, the top-two proceedings (*VLDB*, *SIGMOD*), and the leader of the next class, *ASQ*. Obviously, the first three journals have EDFs that are very close. Our classification heuristic (defined in §4.3) clusters as follows.

Bootstrapping accounts for the variability in the number of citations received: *CACM* does not have the highest point estimate for number of citations, but it does have the highest estimated 0.1 quantile, namely circa 100. *MISQ*'s estimated 0.9 quantile is circa 180, which greatly exceeds 100, so *MISQ* belongs to the same class as *CACM*. We proceed in this way, until a journal or proceedings has a 0.9 quantile smaller than 100: *ASQ*'s estimated 0.9 quantile is circa 85, so *ASQ* is the leader of the next lower class - see Table 2, class 2.

The bold names in Tables 2 and 3 denote the *class leaders*; that is, their estimated (upper) 0.9 quantiles are the highest in their class, but these quantiles are lower than the estimated (lower) 0.1 quantile of the leader of the next higher class (for the highest class this definition needs an obvious amendment).

Our $\alpha = 0.1$ gives four classes for journals and proceedings. (If we replace 0.1 by 0.15, and 0.9 by 0.85, then we obtain five classes; not shown in Table 2.) Obviously, journals and proceedings with no citations received in our sample, constitute the lowest class, namely class 5.

A closer look at Table 2 shows that - rather surprisingly - *Econometrica* (*Econ*) turns up in class 2. We know that this journal is a prestigious journal in the field of econometrics, but we also know that this journal does not publish articles in Information Systems. So we query our database, and find the following. All ($2\times21 = 42$) references that *Econ* receives in our sample (see Table 2), are received from a single article (namely an article sampled from *Journal of Group Decision and Negotiation*, *JGDN*). Figure 2 also shows that *Econ* is an *outlier*: its EDF is clearly less smooth (in 125 of the 1,000 bootstrap replications, *JGDN* is absent, so the estimated probability of references to *Econ* is zero in the range from 0 to 21 citations; *JGDN* is included once in 270 replications, so the EDF jumps to (125 + 270)/1000 for the range from 21 to 42, etc.; in total there are five steps.)

The same number of citations that *Econ* received, is obtained by another journal, namely *IEEE Computer*. The latter, however, receives this number from fourteen - instead of a single - sampled citing publication. Consequently, *IEEE Computer* has a much smoother EDF. (Another example of an outlier is the *Journal of Memory and Cognition*: it is cited twelve times by a single article sampled from *Psychological Review*.)

Figure 3 illustrates another interesting characteristic of our methodology: three journals receive the same number of citations (namely sixteen), and yet they are placed in different classes. Indeed, *ACM Transactions on Information Systems* and the *Journal of Management* are in class 4, whereas the *American Journal of Psychology (AJP)* falls into class 3, which is lead by *Proceedings of IJCAI*. However, since *AJP* is an outlier, we should not let our methodology routinely decide on this journal!

In summary, outliers are easily identified by clearly non-smooth EDFs. In general, outliers in statistics need special handling; also see Pass (1997). For example, we may decide to scrutinize any cited publication medium that receives all its citations from a single source.

6. Conclusions

Measuring the quality of publications is an important issue in practice, and it is a methodological challenge. We propose a novel methodology that samples articles from journals and proceedings, followed by bootstrapping to obtain confidence intervals and by a clustering heuristic to form homogeneous quality classes. This methodology gives ranked lists of journals (ISI and non-ISI) and proceedings, and book publishers respectively. For example, in our Information Systems case-study, class-1 turns out to consist of three journals - *CACM*, *MISQ*, and *Management Science* - and two proceedings - *VLDB* and *SIGMOD*.

So we hope that in the near future our methodology will be refined: smaller sampling error (increase current sample size of 205), smaller time windows (now infinite), correction for size (now not used), revised definition of citing journals and proceedings relevant for Information Systems (e.g., include the Telecommunications category and Interdisciplinary Applications subcategory), addition of books as source of citations, include 'non-English' journals etc. We further hope that our methodology will be applied by others who have the necessary resources: measuring the quality of publications is a task for an institute, not an individual (to collect and store data we used the services of two research-assistants for approximately 50 working days). Finally, our methodology may be applied to other fields besides Information Systems (for computer science and mathematics we refer to the Compumath Citation Index on CD-ROM; see http://www.isinet.com/cp/cocd; for Operations Research (OR) a good starting point is the following web page with approximately 150 OR journals: http://www.informs.org/Biblio/ACI.html).

Obviously, our empirical results are not final. Nevertheless, we hope that our methodology is accepted as better than any alternative currently available!

Appendix 1: Top journals and top proceedings

The top-five US journals according to Holsapple et al. (1993, p. 234) are: *MIS Quarterly* (*MISQ*), *Communications of the ACM* (*CACM*), *Decision Support Systems* (*DSS*), *Information and Management* (*IM*), *Journal of Management Information Systems* (*JMIS*).

The top-five conferences according to Hardgrave and Walstrom (1997, p.123) are: International Conference on Information Systems (ICIS), Hawaii International Conference on System Science (HICSS), IFIP, Decision Support Systems (DSS) conference, Decision Sciences Institute (DSI) conference.

Appendix 2: Population of citing Information Systems journals

The population of citing journals in Information Systems is listed below. The journals have unique identifiers, namely the numbers 1 through 170. Some journals are not sampled: see main text.

1 Academy of Management Journal
2 Academy of Management Review
3 Accounting Review
4 Accounting, Organizations, and Society
5 ACM Computing Surveys
6 ACM SIGPLAN Notices

7 ACM Special Interests Groups
8 ACM Transactions on Computer Systems
9 ACM Transactions on Database Systems
10 ACM Transactions on Information Systems
11 ACM Transactions on Office Information Systems
12 ACM Transactions on Programming Languages and Systems
13 Acta Informatica
14 Administrative Science Quarterly
15 AI Applications
16 AI Magazine
17 American Psychologist, The
18 Annual Review of Information Science and Technology
19 Annual Review of Psychology
20 Applied Artificial Intelligence
21 Artificial Intelligence
22 (Artificial Intelligence in Medicine)
23 Artificial Intelligence Review
24 (AT&T Technical Journal)
25 (Avtomatika Vychislitelnaya Tekhnika)
26 Business Horizons
27 (Business Week)
28 Byte
29 California Management Science
30 Canadian Journal of Information Library Science
31 Chemometrics and Intelligent Laboratory Systems
32 (Cognitive Brain Research)
33 Cognitive Science
34 Communications of the ACM
35 Computer (IEEE)
36 Computer Decisions
37 Computer & Graphics
38 Computer Management
39 Computer Networks and ISDN systems
40 Computer Science and Informatics Journal
41 Computers and Artificial Intelligence
42 Computerworld
43 Computer Journal
44 Data & Knowledge Engineering
45 Data Base
46 Data Management
47 Database
48 Database Programming and Design
49 Datamation
50 Decision Sciences
51 Decision Support Systems
52 Distributed and Parallel Databases
53 (EDP Analyzer / I/S Analyzer / I/S Analyzer Case Studies)
54 EDP Auditor Journal
55 Engineering Applications of Artificial Intelligence
56 European Journal of Information Systems
57 European Journal of Operational Research
58 Expert System Applications
59 Fortune
60 Government Data Systems
61 Harvard Business Review
62 Human Factors
63 Human Relations
64 Human-Computer Interaction 65 IBM Systems Journal
66 IEEE Expert
67 IEEE Software
68 (IEEE Spectrum)
69 IEEE Transactions on Communication
70 IEEE Transactions on Computers
71 IEEE Transactions on Knowledge and Data Engineering
72 IEEE Transactions on Neural Networks
73 IEEE Transactions on Parallel & Distributive Systems
74 IEEE Transactions on Pattern Analysis and Machine Intelligence
75 IEEE Transactions on Software Engineering
76 IEEE Transactions on Systems, Man and Cybernetics
77 IEICE Transactions on Fundamentals of Electr., Comm. and Computer Sciences
78 IEICE Transactions on Information and Systems

79 IFIP Transactions B: Applications in Technology
80 IFIP Transactions C: Communication Systems
81 IMA Journal of Mathematical Control and Information
82 Image and Vision Computing
83 INFOR (Information Systems and Operational Research)
84 Information Management
85 Information Processing and Management
86 Information Processing Letters
87 Information Resources Management Journal
88 Information Sciences
89 Information Society
90 Information and Software Technology
91 Information Systems
92 Information Systems Journal
93 Information Systems Management
94 Information Systems Research
95 Information Technology and Libraries
96 Information, Computer and Communication Policy
97 Information and Management
98 (Infosystems)
99 Interfaces
100 International Journal of Computer Vision
101 International Journal of Intelligent Systems
102 International Journal of Man-Machine Studies
103 International Journal of Software Engineering and Knowledge Engineering
104 Journal of Accounting Research
105 Journal of the ACM
106 Journal of Applied Psychology
107 Journal of Business Strategy
108 (Journal of Chemical Information and Computer Science)
109 Journal of Computer and System Sciences
110 Journal of Computer Information Systems
111 Journal of Cooperative Information Systems
112 Journal of Documentation
113 (Journal of) Group Decision & Negotiation
114 Journal of Information Management
115 Journal of Information Science
116 Journal of Information Systems Management
117 Journal of Information Technology
118 Journal of Intelligent Manufacturing
119 Journal of Intelligent Robot Systems
120 Journal of Logic Programming
121 Journal of Management Information Systems
122 Journal of Marketing Research
123 Journal of Microcomputer Systems Management
124 Journal of Personality and Social Psychology
125 Journal of Strategic Information Systems
126 Journal of Systems and Software
127 Journal of Systems Management
128 Journal of the American Society for Information Science
129 Journal of the American Statistical Association
130 Journal of the Operational Research Society
131 Knowledge Based Systems
132 Lecture Notes in Control and Information Sciences
133 Lecture Notes on Artificial Intelligence
134 Library Software Review
135 Long Range Planning
136 Machine Learning
137 Management Science
138 Methods of Information in Medicine
139 MIS Quarterly
140 Nauchno-Tekhnicheskaya Informatsiya
141 Nauchno-Tekhnicheskaya Informatsiya
142 Network: Computation in Neural Systems
143 Neural Computing
144 Neural Networks
145 Neurocomputing

146 Office: Technology and People
147 Omega
148 Online
149 Online & CDRom Review
150 Online Review
151 Operations Research
152 Organization Behavior and Human Performance
153 Organizational Behavior and Human Decision Processes
154 Proceedings of the Asis Annual Meeting
155 Pattern recognition
156 Pattern recognition Letters
157 Program: News of Computer in British University Libraries
158 Psychological Bulletin
159 Psychological Review
160 RAIRO Informatique Theorique et Applications
161 Science
162 Scientific American
163 Sloan Management Review
164 Software Magazine
165 Software Practice and Experience
166 Software Practice and Expertise
167 System Dynamics Review
168 (Systems, Objectives and Solutions)
169 Very Large Database Journal (VLDB)
170 Wirtschaftinformatik

Appendix 3: Sampling procedure for measuring citations

ISI (1993, p. 12) states: 'An article cited three times in the references of the same SCI© source item is counted as having been cited by that source item once ... In the case of journals, "times cited" is a cumulation of the number of times a specific journal has been named in the different articles referenced by the source items processed for the SCI/SSCI ... data base'. Therefore we let the numbers in Table 1 denote the number of times the citing article in the corresponding row refers to different articles in the journal or proceedings in the corresponding column; in the case of books the number denotes the number of cited books published by the same book publisher. We include self-citations by the authors, since we assume that ISI does the same: it takes much time to check whether the references concern one of the authors of the citing publication.

Our sampling procedure has the following four steps.

1. Select the most recent issue of each citing journal in the population of 170 journal names in Information Systems listed in Appendix 2.

2. Sample without replacement one article in the most recent available issue of the journal found in step 1. (Sampling with replacement is discussed in §4.2, which is on bootstrapping.) Find the individual *output* articles cited by this *input* article, and store these references into the citation data base.

Comments: (i) The data stored include the year of the cited publication, so we can analyse the effects of different time windows. (ii) Obviously, the list of cited publications grows as the sample of citing articles increases. (iii) Cited publications are sorted into one of the following five classes: (1) *ISI journal*: The journal's name is meant. (2) *Non-ISI journal*. (3) *Book publisher*: An example is Wiley; we combine Wiley's US (New York) and UK (Chichester) editions. This class includes publishers of dissertations; for example, Tilburg University Press. Dissertations that are not published, are listed under (5); see below. (4) *Proceedings*: Again, the name is meant; examples are given in Appendix 1. Proceedings are defined as collections of papers presented at conferences, seminars, colloquia, etc. (5) *Remainder*: This class includes technical reports and working papers, as in Holsapple et al. (1993, p. 234). The only measurement that might be of interest is the percentage of the total number of citations falling into this class; see Table 4.

3. Repeat steps 1 and 2 for the second subpopulation (citing proceedings), but take two articles instead of one.

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Table 1: Number of references by citing article A to journals (J), proceedings (P), and book publishers (B) (in a given year *t*)

	J_1	J_2	...	P_1	P_2	...	B_1	B_2	...
A_1	3				1				
A_2	5	1		1	1		2		
...									
A_{205}	12	7		4	9			1	

Table 2: Journals and proceedings ranked on number of citations received in sample of 123 journal and 82 proceeding articles; bold denotes class leader when α = 0.1; only top-four classes displayed

Class 1	**Median**
MIS Quarterly	135
Management Science	132
Communications of the ACM	**123**
Proceedings of the International Conference on Very Large Databases (VLDB)	87
Proceedings of the ACM Conference on Management of Data (SIGMOD)	87
Class 2	
Administrative Science Quarterly	**63**
Artificial Intelligence	55
Journal of Management Information Systems	47
Journal of Personality and Social Psychology	47
Harvard Business Review	45
European Journal of Operational Research	44
Journal of Accounting Research	44
Proceedings of the National Conference on Artificial Intelligence (AAAI)	44
Academy of Management Review	43
Journal of the ACM	42
IEEE Transactions on Software Engineering	42

Econometrica	42
IEEE Transactions on Pattern Analysis and Machine Intelligence	41
Proceedings of the ACM Symposium on Principles of Database Systems (PODS)	41
Accounting, Organizations, and Society	40
Academy of Management Journal	39
Information and Computation	38
IEEE Computer	36
Information Systems Research	36
Journal of Computer and Systems Science	35
Accounting Review, The	35
ACM Transactions on Database Systems	32
International Journal of Human-Computer Studies	32
IEEE Transactions on Computers	31
Decision Sciences	31
Proceedings of the ACM Symposium on Principles of Programming Languages (POPL)	31
Human Relations	30
Journal of the American Statistical Association	30
Pattern Recognition	27
Review of Economic Studies	26
Memory and Cognition	24
Class 3	
ACM Computing Surveys	34
Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI)	**34**
Psychological Review	32
IEEE Transactions on Knowledge and Data Engineering	31
Information and Management	31
ACM SIGMOD Record	30
IEEE Transactions on Systems, Man and Cybernetics	30
Proceedings of the ACM Symposium on the Theory of Computing (STOC)	30
Proceedings of the IEEE International Conference on Data Engineering (ICDE)	30
Proceedings of the International Conference on Logic Programming (ICLP)	29
Proceedings of the International Conference on Information Systems (ICIS)	29
Journal of Applied Psychology	28
Psychological Bulletin	27
Theoretical Computer Science	26
Journal of Experimental Psychology: Learning, Memory and Cognition	26
IEEE Software	24

Machine Learning	24
Neural Networks	24
Proceedings of the Workshop on Case-Based Reasoning (DARPA)	24
Journal of Automated Reasoning	22
Sloan Management Review	22
American Psychologist	22
Organizational Behavior and Human Decision Processes	22
Cognitive Science	21
Cognitive Psychology	21
Proceedings of the International Symposium on Logic Programming (ILPS)	20
Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition	20
Operations Research	19
Journal of the American Society for Information Science (ASIS)	19
Journal of the Operational Research Society	19
Organization Science	19
Proceedings of the IEEE Symposium on Logic in Computer Science (LICS)	19
Proceedings of the International Conference on Information and Communication Technologies in Tourism	19
Journal of Logic Programming	18
Research in Organizational Behavior	18
Journal of Economic Theory	18
Proceedings of the IEEE International Conference on Robotics and Automation	18
Proceedings of the USENIX Conference	18
Information Systems	17
Vision Research	17
AI Magazine	16
American Journal of Psychology	16
Proceedings of the ACM Symposium on Principles of Distributed Computing	16
SIAM Journal on Computing	15
Annals of Mathematics and Artificial Intelligence	15
Biometrika	15
Cognition	15
Journal of Consumer Research	15
Proceedings of the ACM Conference on Research and Development on Information Retrieval (SIGIR)	15
Class 4	
Interfaces	17

ACM Transactions on Information Systems	16
Journal of Management	16
Proceedings of the IEEE Symposium on Foundations of Computer Science (FOCS)	16
Proceedings of the IEEE	**16**
Information Processing and Management	15
International Journal of Production Research	15
Proceedings of the International Conference on Machine Learning (ICML)	15
Annual Review of Psychology	14
Personnel Psychology	14
Journal of Marketing	14
Neural Computation	14
Proceedings of the International Symposium on Computer Architecture	14
Proceedings of the IEEE International Computer Conference (COMPCON)	14
Proceedings of the International Conference on Principles of Knowledge Representation and Reasoning	14
Proceedings of the IEEE Real-Time Systems Symposium	14
American Economic Review	13
International Journal of Distributed and Parallel Databases	13
Pattern Recognition Letters	13
Philosophical Transactions of the Royal Society of London	12
IEEE Transactions on Engineering Management	12
American Sociological Review	12
Journal of Business	12
Journal of Accounting and Economics	12
Journal of Educational Psychology	12
Human Factors	12
Journal of Marketing Research	12
New Generation Computing	12
International Journal of Clinical and Experimental Hypnosis	12
Proceedings of the European Conference on Artificial Intelligence (ECAI)	12
Proceedings of EFOC	12
Proceedings of the American Educational Research Association	12
Proceedings of the Microprogramming Workshop (MICRO)	12
Nature	11
ACM Transactions on Programming Languages and Systems	11
International Journal of Computer Vision	11
ACM SIGSOFT Software Engineering Notes	11
Science of Computer Programming	11

Decision Support Systems	11
Journal of Experimental Social Psychology	11
Journal of Organizational Behavior	11
Long Range Planning	11
IEEE Transactions on Robotics and Automation	11
Journal of Law and Economics	11
Journal of Finance	11
Journal of Management Studies	11
Journal of Information Systems	11
Proceedings of the Conference on Automated Deduction (CADE)	11
Proceedings of the ACM Conference on OO Programming Systems, Languages, and Applications (OOPSLA)	11
Journal of Sound and Vibrations	10
Information Processing Letters	10
BIT	10
Information Systems Management	10
CVGIP: Image Understanding	10
Data Base	10
IEEE Expert	10
Computer Vision, Graphics, and Image Processing	10
Behaviour and Information Technology	10
Quarterly Journal of Economics, The	10
California Management Review	10
Organization Studies	10
Journal of Management Accounting Research	10
Information Week	10
Advances in Consumer Research	10
Journal of Public Policy and Marketing	10
Personality and Individual Differences	10
Artificial Intelligence in Engineering	10
Transactions IECE Japan	10
Proceedings of the Royal Society of London	10
Proceedings of the International Conference on Computer Vision (ICCV)	10
Proceedings of the Australasian Database Conference	10
Proceedings of the International Conference on Measurement and Modelling of Comp. Syst. (SIGMETRICS)	10
Proceedings of the International Workshop on Infrastructure for Temporal Databases	10
IEEE Transactions on Communications	9

Journal of the Royal Statistical Society	9
IEEE Transactions on Information Theory	9
Organizational Dynamics	9
VLDB Journal	9
Scientific American	9
Proceedings of the International Conference on Advanced Information Systems Engineering (CAiSE)	9
Proceedings of the International Conference on Architectural Support for Progr. Languages and Op. Sys	9
Proceedings of the International Workshop on Logic Programming and Non-Monotonic Reasoning (LPNMR)	9
Academy of Management Best Paper Proceedings	9
Proceedings of the Hawaii International Conference on System Sciences (HICSS)	9
Proceedings of the Annual Conference of the Cognitive Science Society	9
Astronomical Journal	8
ACM Transactions on Computer Systems	8
Computer Networks and ISDN Systems	8
Discrete and Computational Geometry	8
Science	8
Journal of the Optical Society of America	8
Proceedings of the International World Wide Web Conference	8
Business Week	8
Quarterly Journal of Experimental Psychology, The	8
U.S.S.R. Computing Mathematics and Mathematical Physics	8
Omega	8
Information Systems and Operational Research (INFOR)	8
Research Strategies	8
Software Engineering Journal	8
Journal of Consumer Affairs	8
Statistics in Medicine	8
Methods of Information in Medicine	8
Proceedings of the ACM Symposium on Discrete Algorithms (SODA)	8
Proceedings of the IEEE Symposium on Visual Languages	8
Proceedings of the IEEE Workshop on Visual Languages	8
Proceedings of the ACM Symposium of Computational Geometry	8
Proceedings of the International Workshop on Advanced Visual Interfaces	8
Proceedings of the International Conference on Cooperative Multimodal Communication	8
ABA Banking Journal	7

AIIE Transactions	7
Annals of Statistics	7
International Journal of Computational Geometry & Applications	7
Lisp and Symbolic Computation	7
Journal of Systems and Software	7
Behavioral and Brain Sciences, The	7
Annals of Tourism Research	7
Biological Cybernetics	7
Computer Aided Design	6
Journal of Real-Time Systems	6
CSVA Acta Technica	6
Proceedings of the Text Retrieval Conference (TREC)	6
International Journal of Operational Research	6
ASCE Journal of Water Resources Planning and Management	6
Engineering Economist, The	6
Journal of Consumer Policy	6
Computers and Chemical Engineering	6
Journal of Sport Psychology	6
Journal of Supercomputing	6
Proceedings of the European Workshop on Learning Robots	6
Proceedings of the Workshop on Functional Programming	6
Proceedings of the International Conference on Genetic Algorithms	6

Table 3: Book publishers ranked on number of citations received in sample of 123 journal and 82 proceeding articles; bold denotes class leader when $\alpha = 0.1$; top-six classes displayed

Class 1	median
Springer-Verlag	**169**
Wiley	143
Addison-Wesley	131
Class 2	
Prentice Hall	**101**
MIT Press	83
Cambridge University Press	76
Class 3	
Morgan Kaufmann Publishers	**57**
Sage Publications	58

Academic Press		55
McGraw Hill		51
Elsevier		39
Lawrence Erlbaum Associates		39
	Class 4	
Oxford University Press		**34**
North-Holland		31
MacMillan		31
Kluwer		29
Jossey-Bass		27
Free Press		31
Benjamin-Cummings		25
JAI Press		24
Houghton Mifflin		21
	Class 5	
University of California Press		**19**
Heinemann		18
Harvard Business School Press		19
University of Chicago Press		20
Freeman		16
Blackwell, Basil		18
Harvard University Press		17
Routledge		17
Harper and Row		16
Pitman		15
AAAI Press		14
Plenum Press		11
Irwin		14
Princeton University Press		12
Tavistock		12
Van Nostrand Reinhold Co.		12
Random House		12
Rand-McNally		12
Guilford Press		12
Microsoft Press		6
Stanford University Press		10
	Class 6	
Simon & Schuster		**10**
Norton		9

Computer Science Press	9
World Scientific Publishing	10
Greenwood Press	8
Basic Books	6
University of Michigan	7
Gorcum, Van	8
Taylor & Francis	8
Clarendon Press	7
Pergamon Press	7
Airlines Electronic Engineering Committee (AEEC)	4
GMD National Research Center for Information Technology	4
Praeger	6
Goodyear	6
Ellis Horwood	5
Little Brown & Co.	6
ACM Press	5
Kent Publishing Co.	6
Harvester	6
American Psychological Association	6
Ablex	6
Dekker, Marcel	4
Yale University Press	6
VDI-Verlag	4
Hogarth	4
Knopf	4
ILR Press	4
IOS Press	4
IEEE Computer Society Press	4
Penguin	4
Ballinger	4
Longman	4
Putnam	4
Lexington Books	4
University of Waterloo	4
National Institute of Standards and Technology	4
Holt, Rinehart and Wilson	4
Scott, Foresman and Co.	4
Batsford, B.T.	4
Doubleday	4

Manchester Business School	4
Harcourt Brace (Javanovich)	4
Century VII Publishing Company	4
Gower	4
West Publishing	4
Cornell University Press	4
Harper Collins	4
Nijhoff, Martinus	4
Methuen	3
Chapman and Hall	4
Research Psychologists Press	4
Mouton	4
Appleton-Century-Crofts	4
Infix	4

Table 4: Citation patterns of journals and proceedings

References from/to	Journal	Proceedings	Book	Remainder
Journal	48.7%	19.4%	23.4%	8.5%
Proceeding	33.5%	32.0%	20.9%	13.5%

Figure 1: Cumulative distribution of top journals and proceedings

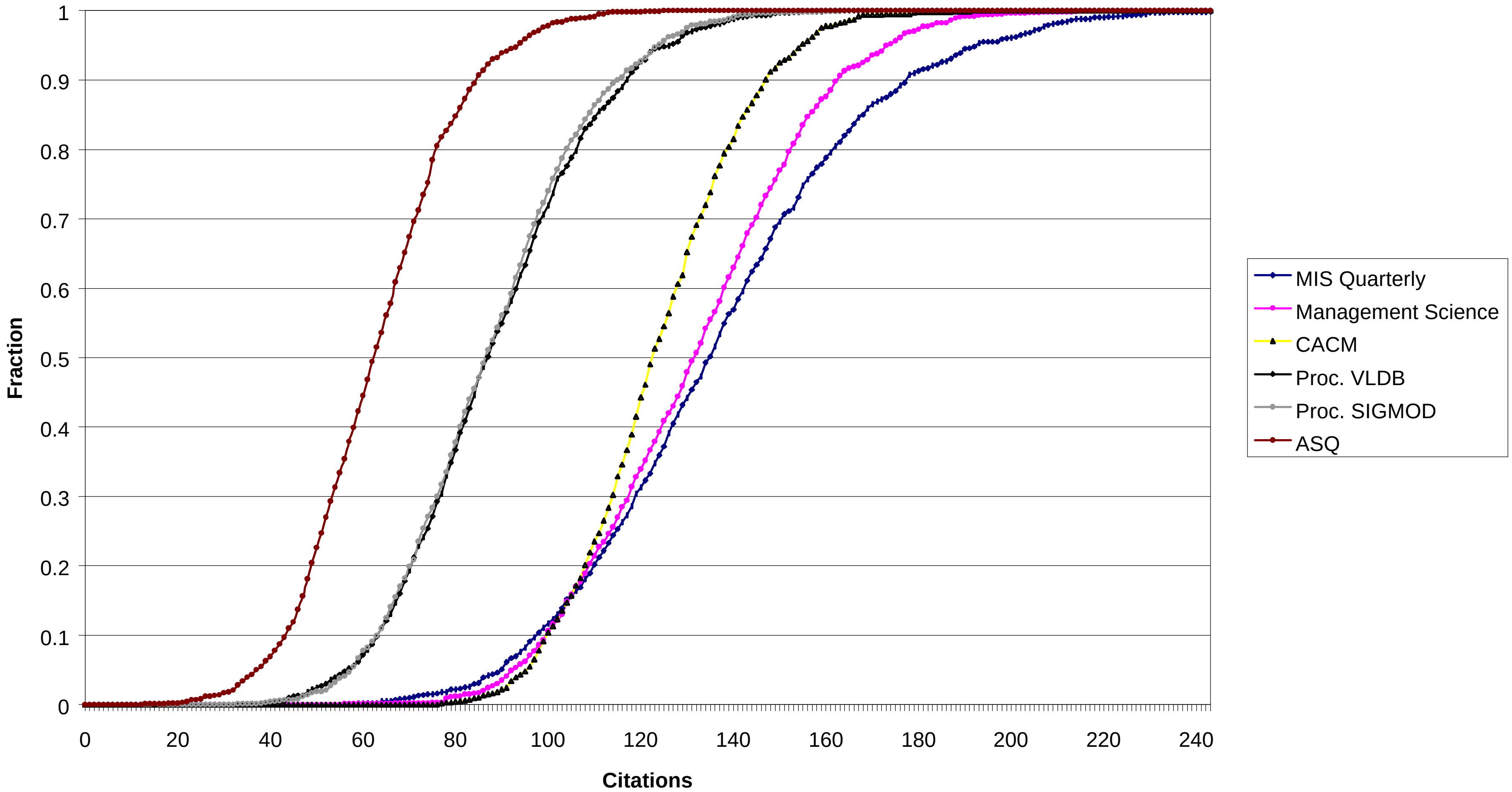

Figure 2: Detecting outliers

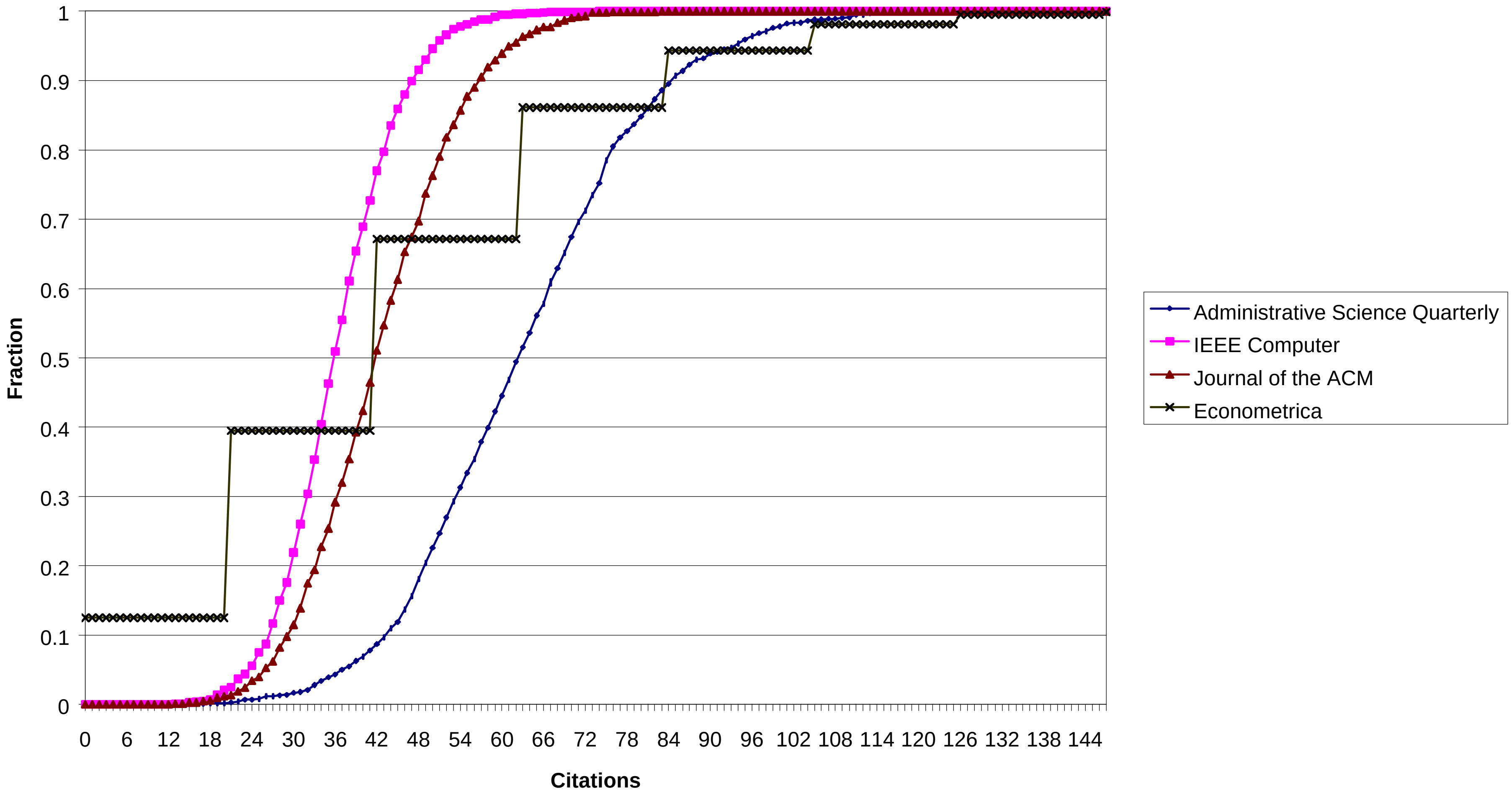

Figure 3: Classifying outliers